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4

September 21, 2000

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APPLICATION NUMBER: ***60/152,487***
FILING DATE: ***September 03, 1999***

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PROV

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR A PATENT under 37 CFR 1.53 (b)(2).

Docket Number	14112-5 USPR	Type a plus sign (+) inside this box→	+

INVENTOR(s)/APPLICANT(s)			
LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
Grudin	Oleg		Montreal, Canada
Frolov	Gennadiy		Montreal, Canada

TITLE OF THE INVENTION *(280 characters max)*

Differential pressure and gas flow transducer with immunity to acceleration

CORRESPONDENCE ADDRESS

James Anglehart
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ENCLOSED APPLICATION PARTS *(check all that apply)*

X	Specification	*Number of Pages* 3	X	Small Entity Statement	
X	Drawings	*Number of Sheets* 2		Other (specify)	

METHOD OF PAYMENT *(check one)*

	A check or money order is enclosed to cover the Provisional filing fees	PROVISIONAL FILING FEE AMOUNT ($)	$75.00
X	The Commissioner is hereby authorized to charge filing fees and credit Deposit Account Number: 19-5113		

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE _____ Date Sept. 2/99

TYPED or PRINTED NAME James Anglehart

REGISTRATION NO. *(if appropriate)* 38,796

[ ] Additional inventors are being named on separately numbered sheets attached hereto

PROVISIONAL APPLICATION FILING ONLY

Burden Hour Statement. This form is estimated to take 2 hours to complete Time will vary depending upon the needs of the individual case Any comments on the amount of time you are required to complete this form should be sent to the Office of Assistance Quality and Enhancement Division, Patent and Trademark Office, Washington, DC 20231, and to the Office of Information and Regulatory Affairs, Office of Management and Budget (Project 0651-0037), Washington, DC 20503 DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO Assistant Commissioner for Patents, Washington, DC 20231

In the United States Patent and Trademark Office

"Express Mail" mailing label number: EH576252816US
Date of Deposit: September 3, 1999

I hereby certify that the attached U.S. Patent Application, informal drawings, transmittal letter, verified statement, declaration and power of attorney, information disclosure statement, and application fee are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner of Patents, Washington, D.C. 20231.

Randall L. Reed

Randall L. Reed

(Signature)

September 3, 1999

Assistant Commissioner of Patents
Box: Provisional Patent Application
Washington, D.C. 20231

Dear Sir:

Transmitted herewith for filing is the Provisional Patent Application of:

Inventor: Grudin, Oleg and Frolov, Gennadiy
For: Differential Pressure and Gas Flow Transducer with Immunity to Acceleration
Attorney Docket Number: 14112-5USPR

Enclosed are:

1. A Specification with 3 pages.

2. 2 sheets of informal drawings.

3. A Provisional Application for Patent Cover Sheet, signed on September 2, 1999 by James Angelhart Reg. # 38,796. (1 page)

4. A Declaration for Small Entity Status Sheet, signed by Oleg Grudin and Gennadiy Frolov on September 2,1999. (1 page)

5. A return receipt post card.

Respectfully submitted,

Date: September 3, 1999

Randall L. Reed

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DIFFERENTIAL PRESSURE AND GAS FLOW TRANSDUCER WITH IMMUNITY TO ACCELERATION

The present invention relates generally to gas flow transducers containing thermoanemometer-type sensing elements. More particularly, the present invention relates to the accuracy improvement of the transducers by increase of their immunity to acceleration.

Background.

A thermoanemometer-type flow transducer contains a functional element sensitive to gas flow passing through a specially designed gas flow assembly [US Patent 4548078]. The physical principle of gas flow measurement is based on flow-induced disturbance of a symmetrical temperature distribution around a heater. This disturbance, caused by the shift of the heated volume of gas in the direction of flow, is usually detected by a pair of temperature-sensitive elements. Typically the flow-sensitive element contains one or two heaters, which warm the gas in a certain region of the flow channel. It also includes at least two temperature-sensitive elements detecting distortion of the temperature distribution in the heated volume of gas. The functions of gas heating and temperature sensing can be separated, for example, as in the sensor with the central heater and two temperature-sensing elements on opposite sides of the heater [US Patent 4548078]. In an other design, the flow sensor may use only two self-heated temperature-sensing elements, which warm the gas and measure the temperature difference simultaneously [H-E. de Bree, P. Leussink, T. Korthorst, H. Jansen, T S J. Lammerink, M. Elwenspoek The μ-flown: A novel device for measuring acoustic flows Sensors and Actuators A (1996), v.54, n.1, pp.552-557]. The differences between such designsare not sufficient for subsequent consideration. In some circumstances gas flow is proportional to the applied differential pressure, and the flow-sensitive transducer can also work as a differential pressure transducer.

Thermoanemometer-type flow or differential pressure transducers are sensitive to acceleration acting in the direction parallel to the detected gas flow. This effect, caused by the shift of the heated volume of gas having lower density than the surrounding colder gas, results in a temperature difference sensed by the two temperature-sensitive elements. Acceleration applied in directions perpendicular to the gas flow causes shift of the heated volume of gas, which does not significantly change temperature difference measured at the two temperature-sensitive elements. Therefore the transducer has low sensitivity to acceleration perpendicular to gas flow. In general, the acceleration-induced output signal is indistinguishable from a flow-induced signal in a single sensor. Sensitivity to acceleration of the considered differential pressure and flow transducers adversely affects the accuracy of the transducers exposed to mechanical disturbances such as vibrations, rotation and displacement.

The purpose of the present invention is to reduce or eliminate sensitivity of the thermoanemometer-type differential pressure and flow transducers to acceleration and other such mechanical disturbances, thus improving their accuracy.

Summary of the invention and description of the drawings

In the present invention, two or more thermoanemometer-type flow-sensitive elements are connected and used such that the parasitic acceleration-induced components of the signals can be

separated from the flow-induced components, and cancelled, thus allowing identification of the flow-induced signals.

In general, this can be accomplished by using a plurality of flow-sensitive elements connected in such a way that flow and acceleration act in different directions (angles) at different flow-sensitive elements. Many different embodiments are possible.

For example, two thermoanemometer-type flow-sensitive elements are connected in a specific way, such that the gas flows through each of the elements in opposite directions. The output signals of the two flow-sensitive elements are processed electronically so that the acceleration-induced components of the signals are cancelled, while flow-induced components of the signals are doubled.

Another combination may also include at least one flow-sensitive element through which no gas flows. Being subjected to the applied acceleration, this reference element generates an output signal which is used to cancel the acceleration-induced component of the element through with the gas flows.

Figs. 1 and 2 show the configuration of the invented differential pressure and flow transducer containing two thermoanemometer-type flow-sensitive elements. The channel for flowing gas connects two elements in series (Fig. 1), or in parallel (Fig. 2). Fig. 3 depicts a schematic of a single flow-sensitive element with acceleration applied to it.

Fig. 4 shows an example of a more complex configuration involving three flow-sensitive elements connected in a triangle.

Fig. 5 shows the configuration of two identically-aligned flow-sensitive elements with flow passing through only one of them.

Description of the preferred embodiment

In Figs. 1 and 2, there are two possible configurations of the invented transducer where two flow-sensitive elements are connected in series (Fig. 1) and in parallel (Fig. 2). In both cases, the gas flowing through the channels passes through the flow-sensitive elements in opposite directions. Therefore heated volumes of gas near the heaters in both flow-sensitive elements (shown as shaded circles) are also shifted in opposite directions causing inverted output signals. When acceleration is applied in the direction parallel to gas flow as shown on Fig.3, heated volumes of gas are shifted in the same direction for both flow-sensitive elements causing increments in output signals which are the same for both sensors. The output signals of the two flow-sensitive elements are then processed by electronic circuitry, such that one signal is subtracted from the other.

Sensor-output-1 = (flow) + (acceleration)
Sensor-output-2 = - (flow) + (acceleration)
Sensor-output-1 - Sensor-output-2 = 2*(flow)

If the two flow-sensitive elements are identical, sensitivity to acceleration of the whole transducer can be reduced theoretically to zero. In practice, the immunity to acceleration may be limited by mismatch of the two sensor elements and calibration of their sensitivities.

The choice of schemes presented in Figs. 1 and 2 depends on the particular application. The transducer with two flow-sensitive elements connected in series has flow impedance two times higher than a single element while the second transducer (Fig. 2) has flow impedance two times lower.

For experimental verification of the invented concept, a prototype of the transducer was assembled on the basis of two AWM2200 mass flow sensors (Honeywell) connected in series by plastic hoses. It was compared with the single AWM2200 sensor. Electronic circuitries of the transducers provided the same sensitivity to differential pressure. Then both devices were rotated in the Earth's gravity. The single AWM2200 sensor has sensitivity to acceleration of 14mV/g while the prototype of the invented transducer is completely immune to rotation within the resolution of the electronic circuitry (less than 1mV).

The invented configuration of the transducer, immune to acceleration, can be realized by a variety of methods. The best results may be obtained with the usage of identical flow-sensitive elements. These flow-sensitive elements may be commercially available sensors as described above or specially designed functional sensing elements.

Among other possible configurations, one is shown in Fig.4, where three flow-sensitive elements are connected in the shape of a triangle. In this case, the output signals of each flow-sensitive element can be written as:

Sensor-output-1 = (flow) + (acceleration)*cos(60°-β)
Sensor-output-2 = (flow) + (acceleration)*cos (60°+β)
Sensor-output-3 = (flow) - (acceleration)*cos(β)

where β is the angle shown in Fig. 4.
This system of three equations with three unknown parameters, (flow), (acceleration) and β, can be solved to cancel influence of the acceleration-induced component of the signal.

Fig. 5 depicts the combination of two flow-sensitive elements with output signals

Sensor-output-1 = (flow) + (acceleration)
Sensor-output-2 = (acceleration)
Sensor-output-1 - Sensor-output-2 = (flow)

Processing of the output signals can thus cancel the acceleration-induced component of the signal.

Applicant or Patentee: Oleg Grudin and Gennadiy Frolov
Application or Patent No.: _____ Atty. Dkt. No.: 1412-5 USPR
Filed or Issued: herewith
Title: "Differential pressure and gas flow transducer with immunity to acceleration"

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS [(37 CFR 1.9(f) and 1.27 (b)] - INDEPENDENT INVENTOR

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- ☒ the specification filed herewith with title as listed above.
- ☐ the application identified above.
- ☐ the patent identified above.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1 9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- ☒ No such person, concern, or organization exists.
- ☐ Each such person, concern, or organization is listed below.

FULL NAME _____
ADDRESS _____
( ) INDIVIDUAL ( ) SMALL BUSINESS CONCERN ( ) NONPROFIT ORGANIZATION

FULL NAME _____
ADDRESS _____
( ) INDIVIDUAL ( ) SMALL BUSINESS CONCERN ( ) NONPROFIT ORGANIZATION

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. [37 CFR 1.27]

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. [37 CFR 1.28(b)]

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF INVENTOR	SIGNATURE OF INVENTOR	DATE
Oleg Grudin		02 Sept 1999
Gennadiy Frolov		02 Sept 1999

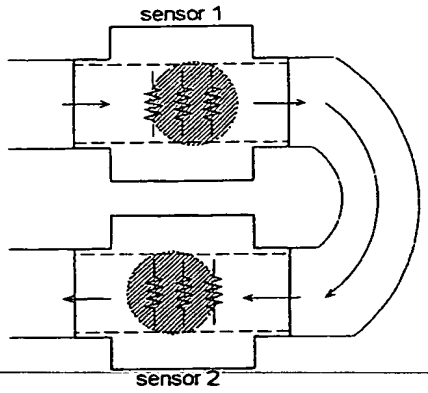

Fig. 1

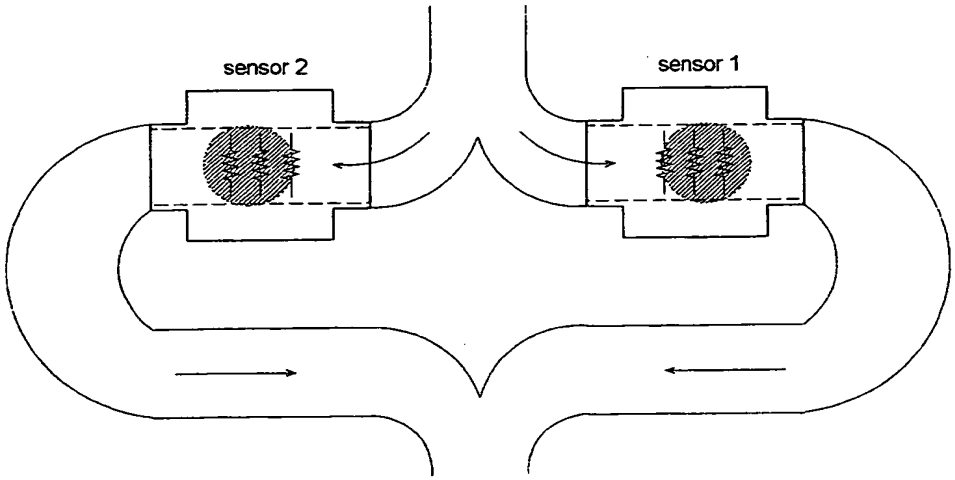

Fig. 2

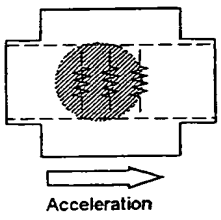

Fig. 3

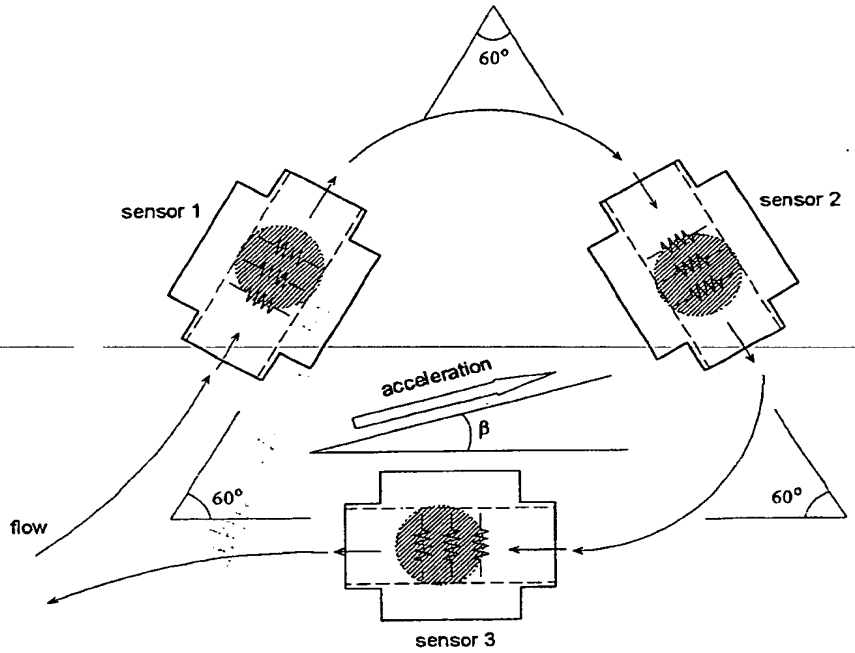
60°
sensor 1
sensor 2
acceleration
β
60°
60°
flow
sensor 3

Fig. 4

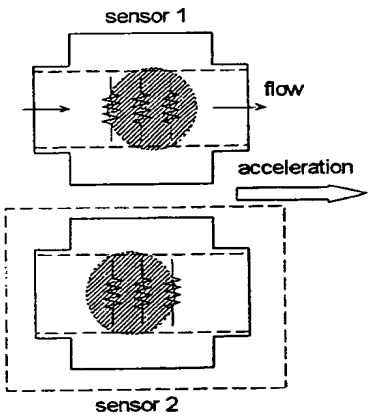
sensor 1
flow
acceleration
sensor 2

Fig. 5